Sensing Hazards with Operational Unmanned Technology (SHOUT) to Mitigate the Risks of Satellite Data Gaps

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Presented by

Robbie Hood

Background

FY2008-FY2010
- NOAA UAS Program, OMAO and NASA Earth Science Airborne Program had a partnership to test and evaluate the Global Hawk, high altitude long endurance (HALE) UAS

FY2013
- Dr. Sullivan sponsored an Analysis of Alternatives (AOA) for Joint Polar Satellite System (JPSS) Data Gap Mitigation conducted by Riverside Technology, Inc.

FY2013
- One of 12 High Merit Ideas in Riverside Technology, Inc. AOA report included "Targeted Observations for High Impact Events" using UAS

FY2014
- NOAA UAS Program was awarded $9M of Disaster Recovery Act (DRA) funding for "Targeted Observations for High Impact Events" project using HALE UAS

Project Goal and Objectives

Overall Goal

- **Demonstrate and test prototype UAS concept of operations that could be used to mitigate the risk of diminished high impact weather forecasts and warnings in the case of polar-orbiting satellite observing gaps**

Objective 1

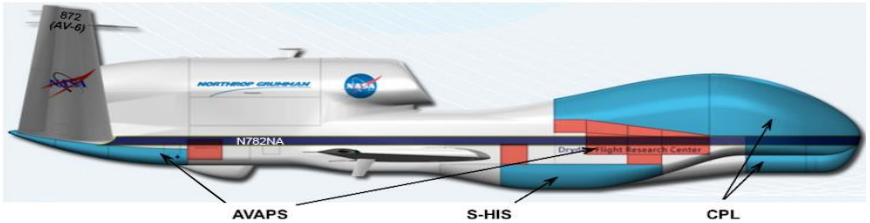
- **Conduct data impact studies**
  - **Observing System Experiments (OSE) using data from UAS field missions**
  - **Observing System Simulation Experiments (OSSE) using simulated UAS data**

Objective 2

- **Evaluate cost and operational benefit through detailed analysis of life-cycle operational costs and constraints**

NOAA Benefit From NASA Hurricane Severe Storm Sentinel (HS3) Experiment

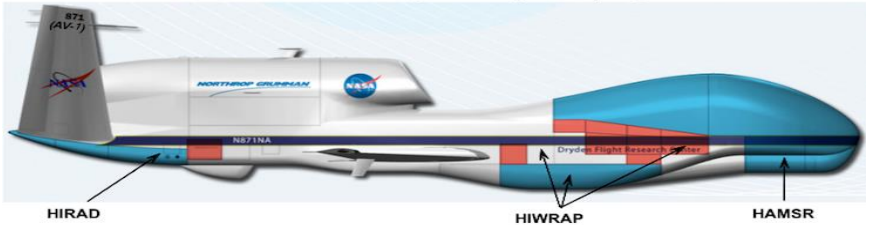
HS3 *Environmental Payload (AV-6) @ WFF '12*



Environment Observations

- **Profiles of temperature, humidity, wind, and pressure (AVAPS)**
- **Cloud top height (CPL)**
- **Cloud top temperature and profiles of temperature and humidity (S-HIS)**

HS3 *Over-Storm Payload (AV-1) @ WFF '12*



Over-storm Observations

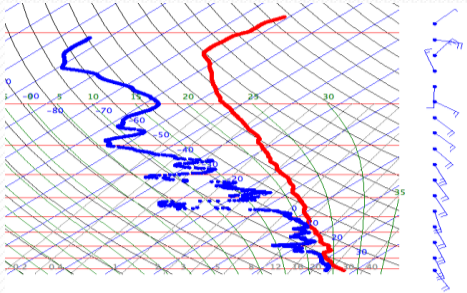
- **Doppler velocity, horizontal winds, and ocean surface winds (HIWRAP)**
- **Profiles of temperature and humidity and total precipitable water (HAMSR)**
- **Ocean surface winds and rain (HIRAD)**

SHOUT Global Hawk Instrumentation

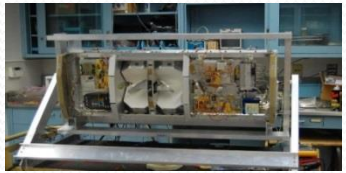
Airborne Vertical Atmospheric Profiling System (AVAPS)

PI: Terry Hock, NCAR
Measurements: Temperature, Pressure, wind, humidity vertical profiles; 88 sondes per flight

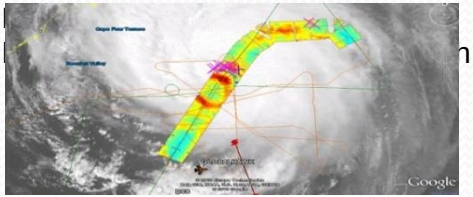
~80-115 hPa



High Altitude Monolithic Microwave Integrated Circuit (MMIC) Sounding Radiometer (HAMSR)

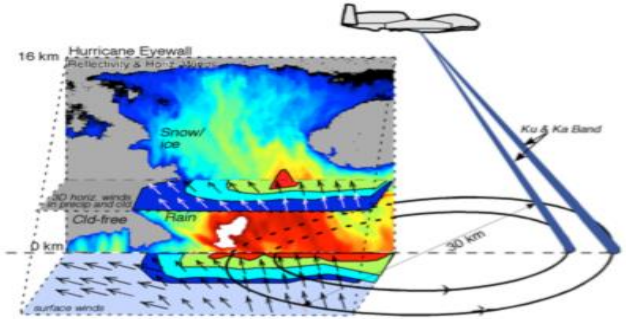


PI: Dr. Bjorn Lambrigtsen, Jet Propulsion Laboratory
Measurements: Microwave radiometer sounder operating at 25 spectral channels in 3 bands (50-60 GHz, 118 GHz, and 183 GHz): 3-D distribution of temperature, water vapor, and cloud liquid water;

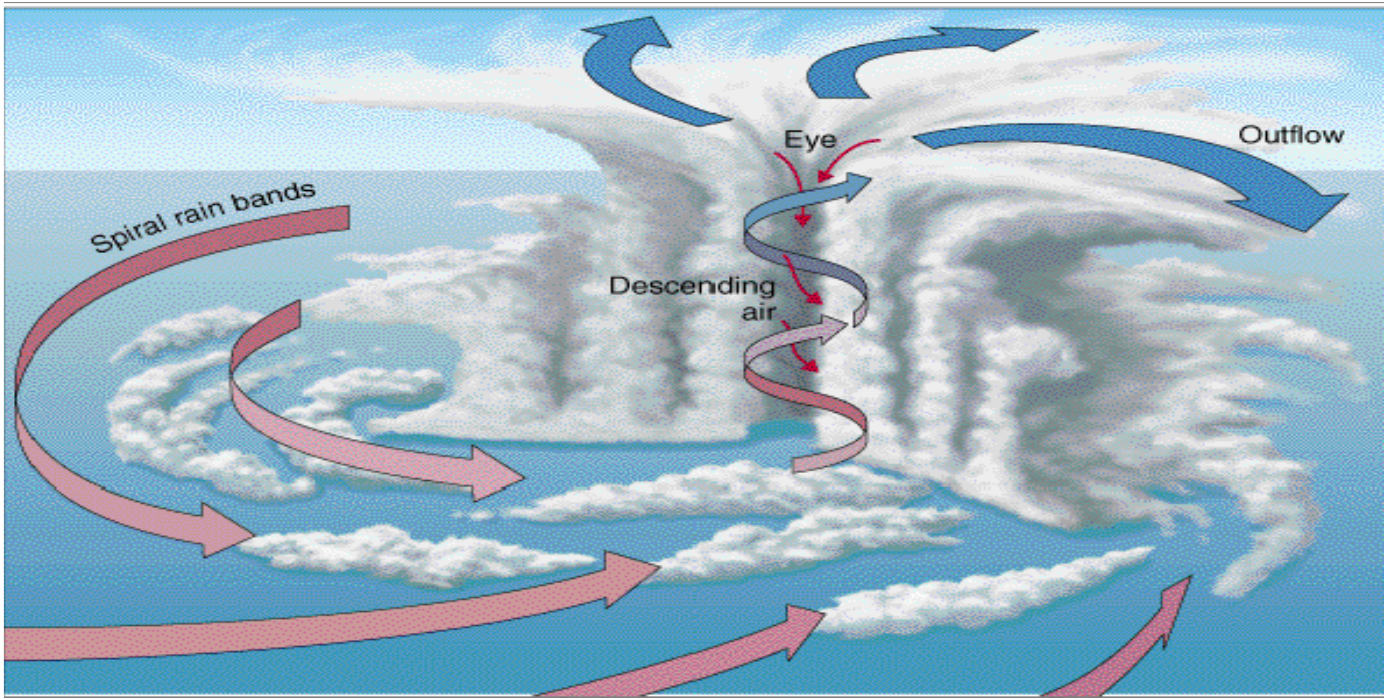


High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)

PI: Dr. Gerald Heymsfield, NASA GSFC
Measurements: Dual-frequency (Ka- and Ku-band), dual beam, conical scanning Doppler radar: 3-D winds, ocean vector winds, and precipitation;

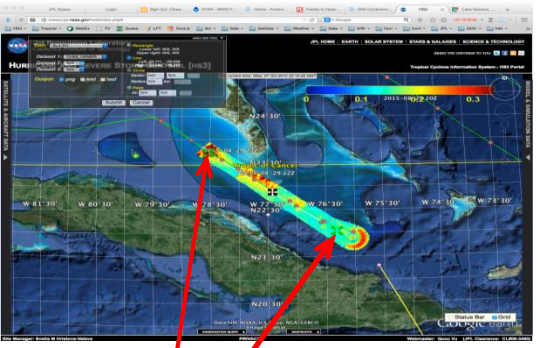


General Structure of a Hurricane

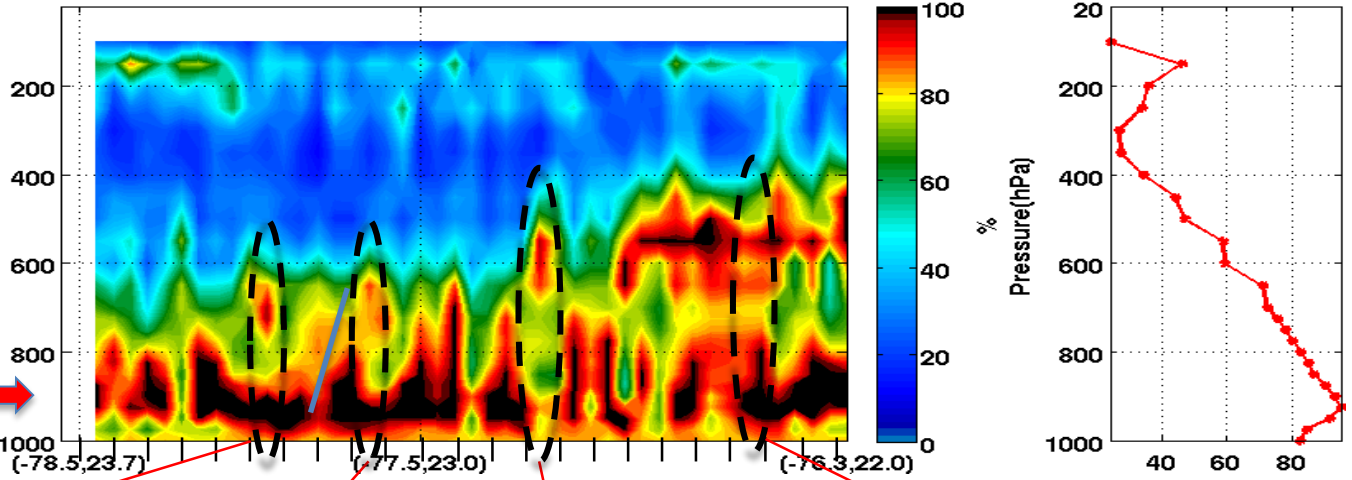


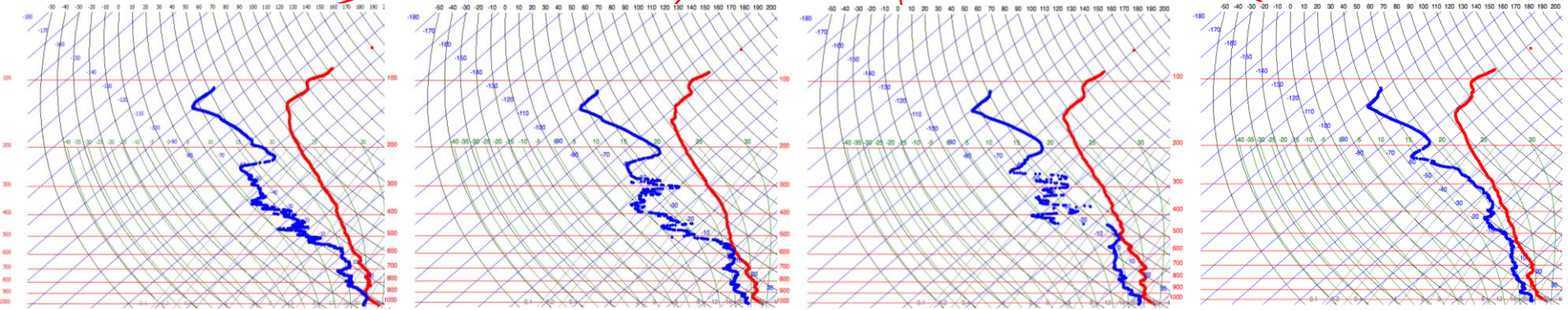
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

HAMSR vs. Dropsondes (Erika #2)



Slicing tool between these end points

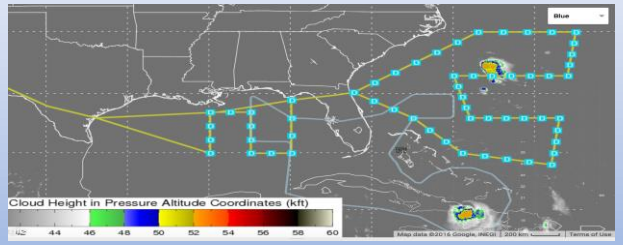




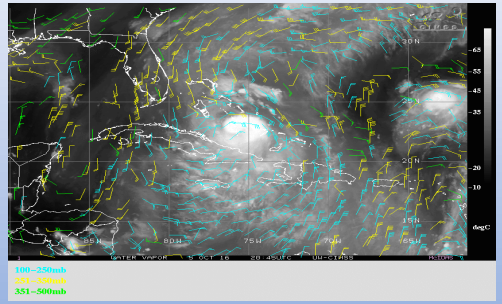
2016 NOAA SHOUT: Matthew (05-06 Oct 2016)

Mission Highlights

- NASA AFRC to NASA AFRC; take-off: 0256 UTC; landing: 0340 UTC
- Objectives: sample HWRF/ECMWF model sensitive regions: GMex (upper-level trough) & U.S. SE coast (ST ridge); sample outflow north of Matthew

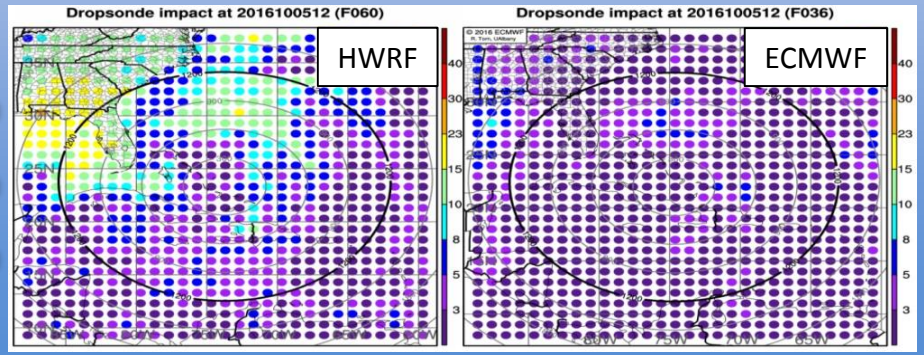


- Global Hawk track
- 24h 44m mission
- 61 GPS dropsondes



CIMSS GOES water vapor AMVs showing outflow around the northern semicircle of Matthew

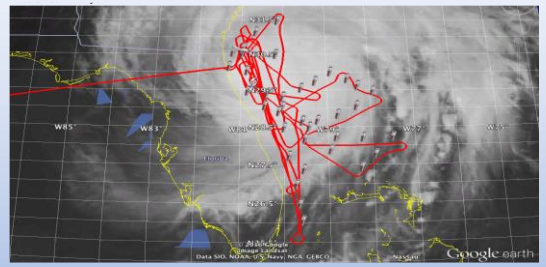
Sensitivity targets for reducing uncertainty amongst the model ensemble members



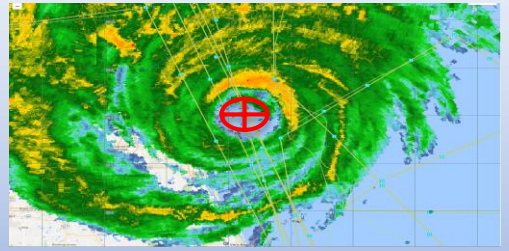
2016 NOAA SHOUT: Matthew (07-08 Oct 2016)

Mission Highlights

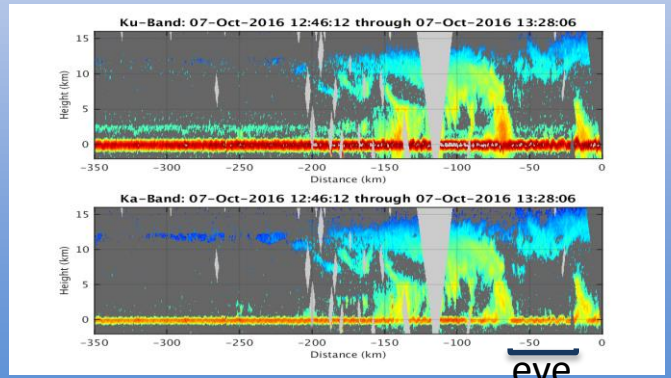
- NASA AFRC to NASA AFRC; take-off: 0224 UTC; landing: 0230 UTC
- Objectives: sample the inner core of Matthew & upper-level outflow



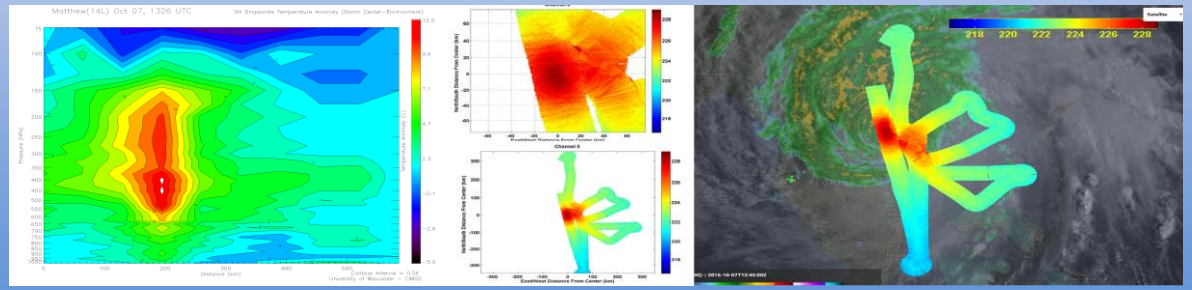
- Global Hawk track
- 24h 06m mission
- 39 GPS dropsondes



Center Drop
1326z
944.5 hPa
5 kt @ 175



HIWRAP x-section:
center crossing (1246-1328 UTC)

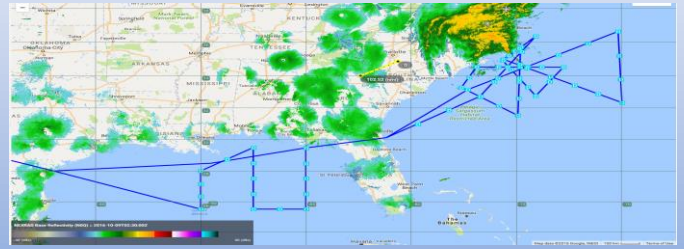


TC warm core analyses derived from (left) GH dropsondes and RAOBs and (center, right) HAMSR Channel 5 (54.4 GHz; weighting function ~150 hPa).

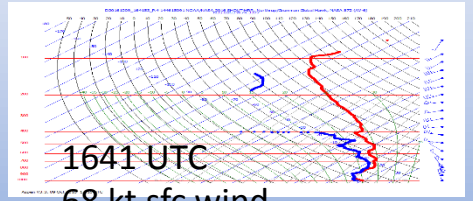
2016 NOAA SHOUT: Matthew (09-10 Oct 2016)

Mission Highlights

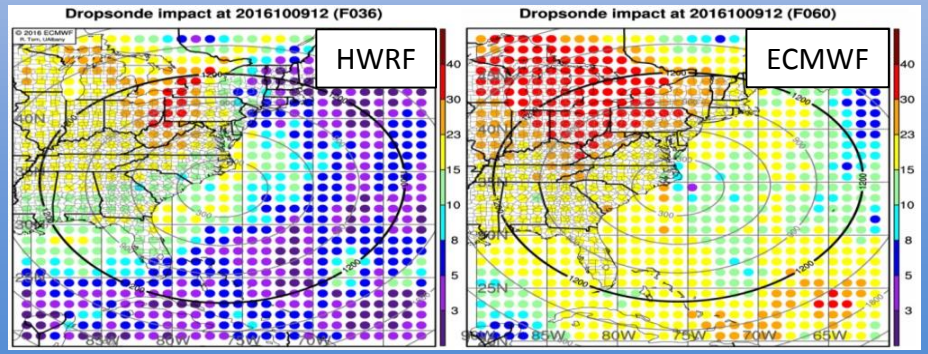
- NASA AFRC to NASA AFRC; take-off: 0300 UTC; landing: 0347 UTC
- Objectives: Sample Matthew & model sensitivity areas (HWRF and ECMWF) E of and near the storm environment, and in the GMex (SE advance of E coast trough).
- NHC declared post-tropical at 0900 UTC (GPS sondes >> maintain H-force winds)

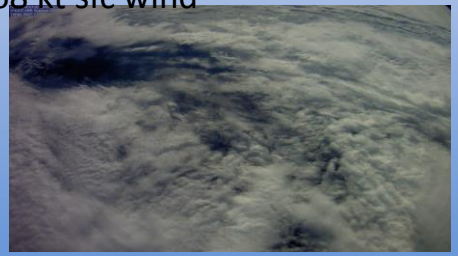


- Global Hawk track
- 24h 47m mission
- 62 GPS dropsondes



Sensitivity targets for reducing uncertainty amongst the model ensemble members





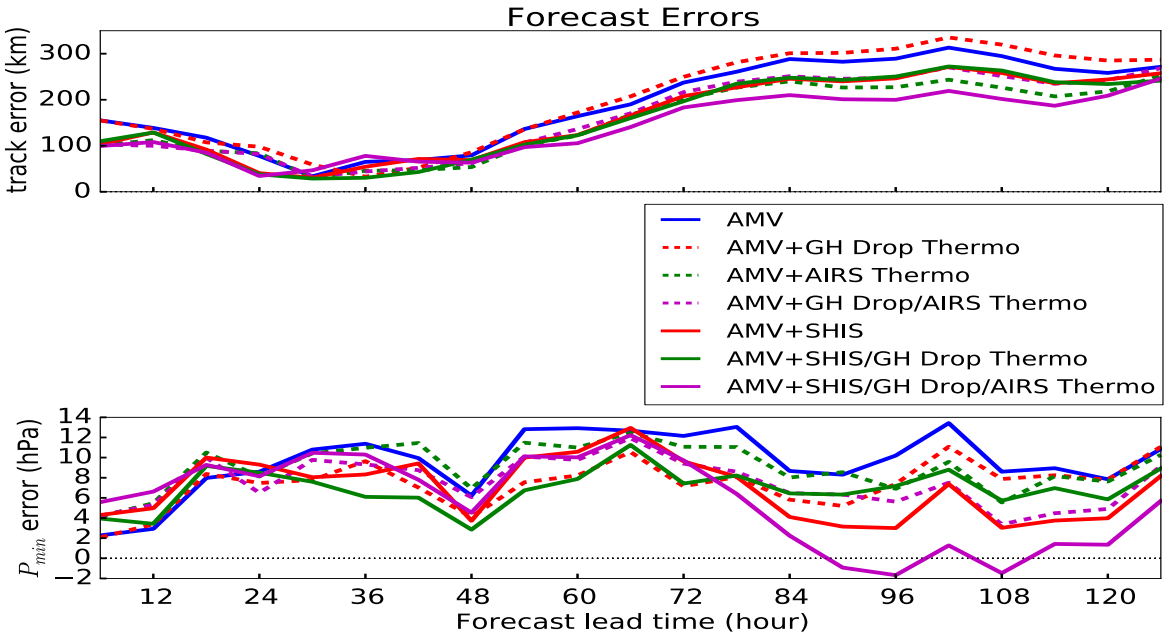
Global Hawk HDVIS camera: near the center of Matthew (1910 UTC)

Preliminary Data Impact Study for Hurricanes

DATA COMPARSIONS

- **AMV - Wind observations from satellite Atmospheric Motion Vector products**
- **GH Thermo - Temperature and humidity observations from Global Hawk dropsondes**
- **AIRS Thermo - Temperature and humidity observations from satellite *(AIRS – Atmospheric Infrared Sounder)***
- **SHIS – Temperature and humidity observations from Global Hawk remote sensor *(S-HIS – Scanning High Resolution Interferometer Sounder)***

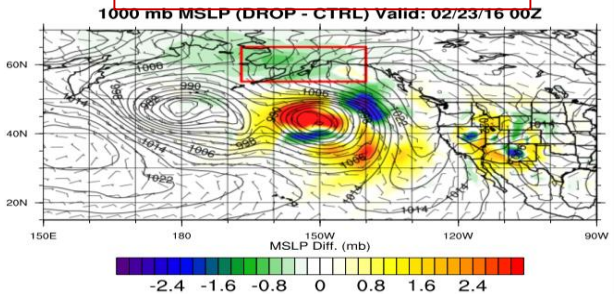
Absolute errors for hurricane track and pressure minimum
(Values approaching zero are improving errors)



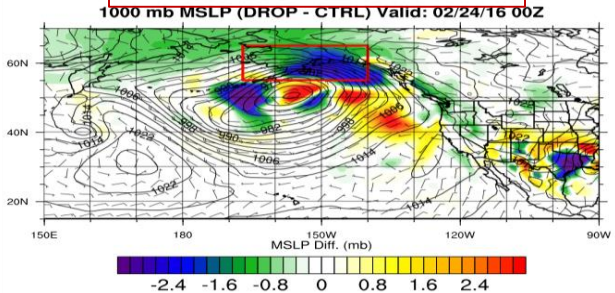
Preliminary Data Impact Study for El Nino Weather Systems

- Global Hawk dropsonde data from 2016 El Nino Rapid Response Experiment input into NWS Global Forecasting System during post-event data impact study
- Comparison of error improvements for Mean Sea Level Pressure (MSLP) forecasts at 24, 48, and 72 hours
- In graphics below, greens and blues are improving errors. Yellows and reds are worsening errors

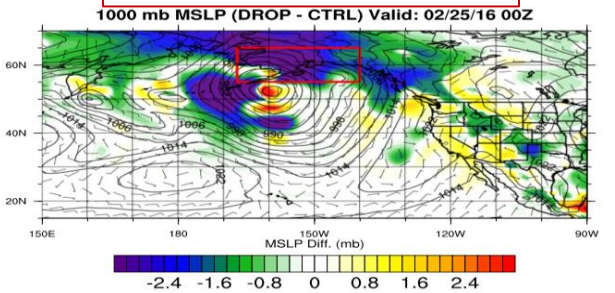
24 hour forecast



48 hour forecast



72 hour forecast



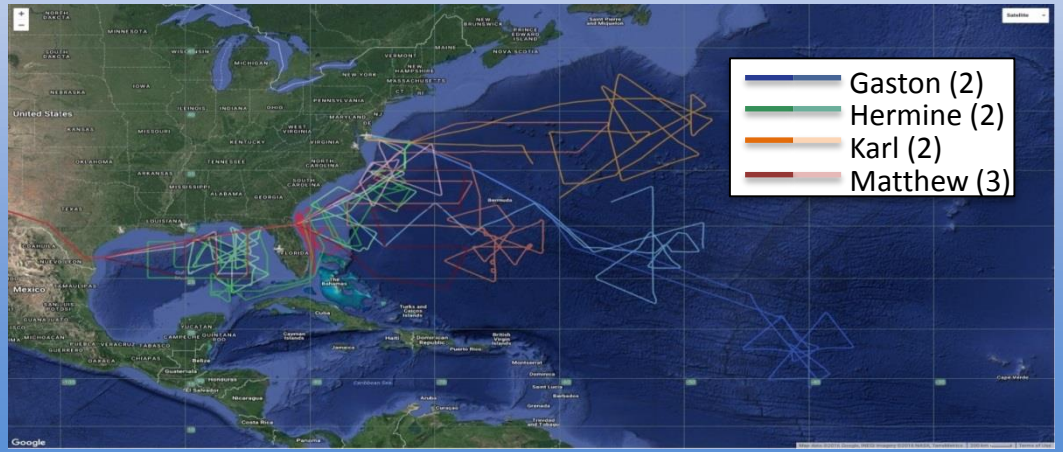
For this weather system, MSLP forecasts are improved for 1-3 day forecasts over Alaska and central USA using Global Hawk dropsonde data

Preliminary Cost and Operational Feasibility Study

Alternative	Platform and payload startup costs	Annual costs for platform, payload, staff
NOAA/NASA partnership with refurbished US Air Force Global Hawk	$7,229K	$11,536K based on 1236 flight hours
NOAA-only operations with refurbished US Air Force Global Hawk	$14,994K	$11,883K based on 1236 flight hours
NOAA/NASA partnership with current NASA assets		$3,423K based on 268 flight hours
Future HALE UAS	In process	In process

SHOUT 2016 Summer Deployment

- 9 flights Total -- 3 consecutive flights on Matthew
- 213 flight hours – 80% on station time
- 647 sondes deployed -- Record 90 sondes in a single flight,
- SHOUT team was on call for 10 consecutive weeks
- Supported virtually from remote locations
- Reduced staffing footprint over previous campaigns split between both coasts



Contact Information

UAS Web Site: http://uas.noaa.gov/

Questions should be directed to:

Robbie Hood - NOAA UAS Program Director
(robbie.hood@noaa.gov / 303-905-3411)

Backup Slides

Thermodynamic Observations for Tropical Cyclones

Obs	TPIO – Validated Requirements			HAMSR Capabilities (TRL – 7/8)			AVAPS Dropsonde Capabilities (TRL – 7/8)		
	VR	HR	A	VR	HR	A	VR	HR	A
Temp. Profiles	*O* 500m *R* 45 m	*O* 50 km *R* 1 km	*O* 1 K *R* 1 K	1 km	2 km	0.5 K	5 – 15 m	< 1 km	0.5 K
Pressure Profiles	*O* - 9 m *R* 45 m	*O* 10 km *R* 1 km	*O* 1 hPa *R* 1 hPa	N/A	N/A	N/A	5 – 15 m	< 1 km	0.1 hPa
Humidity Profiles	*O* 1 km *R* 90 m	*O* 20 km *R* 4 km	*O* 8% *R* 20%	2 km	2 km	15 – 20%	5 – 15 m	< 1km	5%

Obs – Observations Temp - Temperature VR – Vertical Resolution HR – Horizontal Resolution A- Accuracy
***O*- Operations *R* – Research**

Wind Observations for Tropical Cyclones

Obs	TPIO – Validated Requirements			HIWRAP Capabilities (TRL – 7/8)			HIRAD Capabilities (TRL – 6/7)			AVAPS Dropsonde Capabilities (TRL – 7/8)		
	VR	HR	A	VR	HR	A	VR	HR	A	VR	HR	A
WS Prof.	*O* 500 m	*O* 50 km	*O* 1 m/s	500m	1 km	0.5 K	N/A	N/A	N/A	5- 15 m	< 1 km	0.5 m/s
	R 100 m	*R* 50 km	*R* 1 m/s									
WD Prof.	*O* 500 m	*O* 10 km	*O* 10 deg	500m	1 km	15 deg	N/A	N/A	N/A	5- 15 m	< 1 km	10 deg
	R 100 m	*R* 1 km	*R 10 deg*									
Sfc. WS	N/A	*O* 1 km	*O* 1m/s	N/A	1 km	2 m/s	N/A	1-2 km	1 - 5 m/s	N/A	< 1 km	0.5 m/s
	N/A	*R* 12 km	R 2 m/s									
Sfc WD	N/A	*O* 2.5km	*O* 10 deg	N/A	2 km	15 deg	N/A	N/A	N/A	N/A	< 1 km	10 deg
	N/A	*R* 12 km	*R* 20 deg									

VR – Vertical Resolution HR – Horizontal Resolution A- Accuracy WS – Wind Speed WD – Wind Direction
***O*- Operations *R* – Research**

NASA Global Hawk

- **NOAA Flight Level: ~ 55-63,000 ft**
- **Duration: ~26 hr**
- **Range: 11,000 nm**
- **Payload: 1,500+ lbs**
- **Deployment Sites:**
  - ***NASA Wallops Flight Facility (Wallops Island, VA)***
  - ***NASA Armstrong Flight Research Center (Edwards AFB)***
- **Payload Candidates**
  - ***Dropsondes – in situ vertical temperature, moisture, winds***
  - ***Remote Sensors – vertical temperature, moisture, winds***
  - ***Remote Sensors – ocean surface wind speed and cloud structures***